ABSORPTION AND METABOLISM

IN

OBSTRUCTION OF THE PANCREATIC DUCT.

BY

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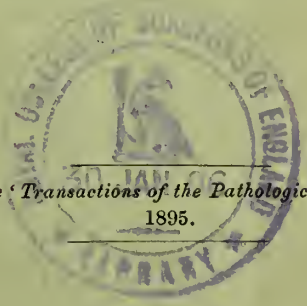

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Absorption and metabolism in obstruction of the pancreatic duct.

By Vaughan Harley, M.D.

It being of particular interest to investigate what changes occur in the absorption of food as well as metabolism in that diseased condition in which so important a juice as the pancreatic is prevented from entering the alimentary canal, I venture to bring forward the following facts:

As early as 1832 Bright[1] stated that in diseases of the pancreas large quantities of fat were found in the stools.

In 1862 Dr. George Harley[2] pointed out that the solidification of oil taken by the mouth in the stools was a reliable sign of occlusion of the pancreatic duct.

Experimentally von Mering and Minkowski[3] showed that in dogs in which the pancreas had been entirely extirpated, and the animals thus rendered diabetic, large quantities of fat occurred in the stools.

Subsequently Abelmann[4] investigated the metabolism of dogs from which the pancreas was either partially or totally extirpated; in this research he showed that von Mering's and Minkowski's observations were perfectly correct, and that animals thus operated on were unable to absorb as much fat as normal animals. In fact, while olive oil was entirely unabsorbed, milk fat was only absorbed in small quantities. He further found that while the absorption of proteids was very much diminished, carbohydrates were not absorbed in the normal quantity.

In September, 1893, while working in the Physiological Laboratory of Turin, I found that in a dog from which almost the entire pancreas had been removed, the body weight fell from 8·5 kilos. to 5·05 kilos. in the space of two months; at the same time the urine contained no sugar. The fæces of all the animals that I have experimented upon

[1] Bright, 'Med.-Chir. Trans.,' 1832.

[2] George Harley, "Complete Obstruction to the Bile and Pancreatic Ducts," 'Trans. Path. Soc.,' vol. xiii, 1862, p. 118.

[3] Von Mering and Minkowski, 'Arch. f. exp. Path. u. Pharm.,' vol. xxvi, 1889, p. 371.

[4] Abelmann, 'Inaug. Diss., Dorpat,' 1890.

had a most peculiar foul smell; this fact, trifling as it may appear, is nevertheless of importance, as I have found it invariably to occur when the dogs were fed on raw meat, which even often reappeared in the stools apparently unaltered; when fat was given it also reappeared in large quantities in the stools. Before describing a human case, I shall give, for the purpose of comparison, the results of the analyses in a dog which lived for two months after an almost total extirpation of the pancreas. The dog lost considerable flesh, although the urine at no time contained any sugar, for which it was repeatedly examined by fermentation, phenyl-hydrazine, and Fehling's tests. The urine, on the other hand, contained not only acetone, but also aceto-acetic acid in small quantities. The fæces always contained undigested food, and had the remarkably foul odour above described.

TABLE 1.—*Showing the absorption of nitrogen in a dog in which the pancreas had been almost extirpated; the animal lost flesh considerably, but the urine never contained sugar, owing to some very small portions of the tail of the pancreas having been left.*

Day.	Weight.	Food.	Urine.	Fæces.			P. cent. of N. absorbed.
	Kilos.	N. in grams.	N. in grams.	Quantity in grams.	N. in grams.	Total N. for 4 days.	
1	5·700	No food	1·945	None			
2	5·700	17·618	2·193	80·2	5·900	14·469	17·88
3	5·500		2·260	60·3	3·100		
4	5·450		3·013	66·4	2·221		
5	5·300	No food	1·147	67·0	3·248		
6	5·150		1·520	18·7	0·644		

On the first day, as shown in Table 1, no food was given, while during the next three days the animal was given meat containing 17·618 grams of nitrogen. With the first and last meal charcoal was given to indicate how long the fæces passed, belonged to this diet; the black colour disappeared on the sixth day. The stools passed on the sixth day, which did not contain any charcoal, are therefore not reckoned in calculating the total quantity of nitrogen unabsorbed.

That even fasting animals pass fæces we know from the experiments of Voit, and that the same holds good in human beings has been further shown by observations made on various fasting individuals. The fæces passed on the sixth day correspond in all probability to

the fasting stool, which is supposed to be derived from an excretion into the alimentary tract, as described by Hermann, Ehrenthal, Bernstein, and F. Voit.

It is interesting to note that when food was given on the second morning the animal passed some of the black-coloured stools in the evening. The stools were each day collected in the morning before giving the food, but for the purpose of convenience they are entered in the above table as if passed during that day.

It is seen in Table 1 the quantity of nitrogen given in the meat was 17·618 grams, while the quantity eliminated from the alimentary canal was 14·469, consequently only 17·88 per cent. of the nitrogen given was absorbed. In reality, in all probability somewhat more was absorbed, as some of this nitrogen found in the fæces would correspond to that which is normally eliminated in a fasting animal.

In the analysis of the urine we find that during the three days on which the animal was fed the quantity of nitrogen eliminated was almost uniform; at the same time the animal could not be said to be at nitrogen equilibrium, as it continuously lost weight.

The quantity of nitrogen eliminated in the urine and fæces was more than was really given to the animal in the diet, so that some of the nitrogen contained in the urine was derived from a breaking down of the tissues themselves, and hence the source of the loss of weight.

The loss of weight in this experiment can be partly explained by the diminished absorption of food from the alimentary canal, but this alone does not seem a sufficient explanation.

Abelmann found that when he removed the entire pancreas, from 22 to 58 per cent. of the proteids given to his dogs was absorbed, while when the gland was only partially removed, the absorption ratio rose from 40 to 83 per cent.

It is therefore shown by these experiments that the absorption of proteids from the alimentary canal is markedly affected in pancreatic disease, and that, as will be seen later, it is in reality not much less affected than the absorption of fat which has hitherto been generally believed to be, if not the only, at least the principal kind of food affected.

If we now turn to the effects on the absorption of mutton fat produced by extirpation of the pancreas in dogs, we find that the

proportion varies with the period which has elapsed since the operation.

TABLE 2.—*Showing the absorption of mutton fat, after almost complete extirpation of the pancreas; one twentieth of the tail of the pancreas being left. The experiment begins fifteen days after the operation.*

Day.	Weight.	Fat in food.	Fæces.		Per cent. absorbed.
	Kilos.	Grams. Total.	Quantity. Grams.	Fat. Grams.	Fat.
1	7·670	36·40	19·3	26·71	26·62
2	7·600		106·0		
9	6·850		116		
10	6·830	75·81	174	47·05	37·94
11	6·720		53		
15	6·500		none		
16	6·350		9·620		
17	6·250	46·95	8·037	44·885	4·4
18	6·100		9·914		
19	5·900		10·936		
20	5·900	no food	6·378		

Charcoal was given as indicator in this case in the same manner as previously described. In the above table it is seen that in the first two periods of two and three days respectively 26·62 to 37·94 per cent. of the fat given was absorbed, the largest absorption taking place when the largest quantity of fat was given; while during the third period, when the animal was in a weaker condition, and would not take so much food, the quantity of fat absorbed was much less, being only 4·44 per cent.

Abelmann found that after the total extirpation of the pancreas in his dogs no fat was absorbed, whereas in partial extirpation from 25 to 59 per cent. of the quantity given was absorbed. Milk fat, however, proved an exception to this rule, for he found in total extirpation from 28 to 33 per cent. of the milk fat was absorbed.

In other experiments in which I have endeavoured to ascertain the amount of fat absorbed from the intestinal canal of dogs after either partial or total extirpation of the pancreas, I have in all cases found a very marked decrease from the normal amount of fat absorbed, but the above samples are the best of them.

In a paper on the absorption of milk fat recently published in the 'Journal of Physiology,'[1] I showed that while a normal dog fed on milk absorbs from 21 to 46 per cent. of the fat given in seven hours, in a dog from whom the pancreas had been entirely removed no absorption of milk fat whatsoever could be definitively found to have occurred in this space of time.

With these preliminary remarks I will proceed to narrate an exceptionally characteristic case of pancreatic duct obstruction in which, through the kindness of Dr. Auld, of Wimborne, I had the opportunity of making a series of analyses while the patient was on a fixed diet.

The patient was a boy aged thirteen, who, after recovering from scarlet fever, was attacked by severe gastritis in February, 1894. He had previously suffered from an attack of acute nephritis. Two months after the scarlet fever an offensive smell was noticed by persons coming near him, and this was found to be due to an oily excretion which collected on the seat of his trousers.

On examining his fæces Dr. Auld found them of a light brown colour, soft, and containing undigested food. A large quantity of oil floated about them; on cooling, the oil solidified into a hard beeswax-like cake. A motion followed immediately upon each meal, associated with pain in the rectum, which was found to be due to an inflammatory congestion of the mucous membrane and an appearance of villous growths.

When Dr. Auld brought the boy to Dr. George Harley on the 4th October, 1894, he was passing every tenth day or so a large quantity of more or less bright orange-coloured oily fluid, which immediately gave rise to the supposition that he was labouring under some form or another of pancreatic disease. His abdomen was consequently carefully examined, without any pain, tenderness, or swelling of any kind being found in the pancreatic region. The oily stools were, however, so characteristic of the absence of pancreatic juice that he was put under the appropriate treatment for that affection.

When I examined the urine in June it contained 1·51 per cent. of urea, no acetone or aceto-acetic acid, nor any sugar. At this time the boy weighed 78 lbs. Some of the oily matter he passed was sent to me for analysis in July, and I found it consisted of small quantities of neutral fat and soap, and large quantities of fat acids.

[1] Vaughan Harley, 'Journal of Physiology,' vol. xviii, 1895, p. 1.

During December, 1894, all medicines were stopped, and he was placed for four days entirely on milk diet.

On this diet the fæces were of a yellowish-white colour, and of the consistence of a soft cream cheese. They contained a few yellowish lumps like beeswax, and smelt like extremely bad cheese. They contained a small quantity of bile acids and urobilin. From this, and the absence of any jaundice or bile in the urine, the bile-duct was evidently pervious. The results of a quantitative analysis are given below in a tabular form.

TABLE 3.—*Boy, age thirteen, suffering from probable obstruction to the pancreatic duct.*

Date.	Weight.		Milk diet.			
	Kilos.	lbs.	Quantity. c.c.	N. Grams.	Proteids. Grams.	Fat. Grams.
December 13	37·8	84	Ordinary diet	—	—	—
„ 14	37·8	84	3976	13·12	82·5	196·85
„ 15	37·6	83·5	3976	13·12	82·5	196·85
„ 16	37·4	83	3976	13·12	82·5	196·85
„ 17	37·4	83	3976	13·12	82·5	196·85
„ 18	37·6	83·5	Ordinary diet	—	—	—
„ 19	37·8	84	Ditto.	—	—	—

Date.	Urine.				Fæces.			
	Quantity c.c.	Re-action.	Sp. gr.	N. Grams.	Quantity. Grams.	N. Grams.	Proteids. Grams.	Fat. Grams.
December 13	—	—	—	—	—	—	—	—
„ 14	1680	acid	1007	10·017	—	—	—	—
„ 15	1960	acid	1007	10·272	257·84	1·149	8·931	19·98
„ 16	2240	acid	1008	12·096	688·02	5·631	35·194	149·72
„ 17	1960	acid	1009	10 027	576·40	4·859	30·368	137·87

The analysis of the four days given in Table 3 show that, as far as the urine is concerned, the quantity of nitrogen excreted is comparatively equal. During the first two days on a milk diet he lost a pound in weight (14th and 15th), the next two days (16th and 17th) his weight remained the same, and the nitrogen eliminated in the fæces and urine was practically the same. In calculating the absorption and metabolism in his case the results of the 16th and 17th of December only are employed.

As regards the absorption of nitrogen and fat from the alimen-

tary canal I will compare the average results of these two days with that found by Rübner[1] in a healthy man on a milk diet.

TABLE 4.—*Comparing the quantity of nitrogen and fat absorbed from the alimentary canal on milk diet in a healthy man (Rübner) and the patient suffering from probable obstruction to the pancreatic duct.*

Condition.	Milk contained			Fæces contained				Absorbed.			
	Quantity. c.c.	N. Grams.	Fat. Grams.	N Grms.	%	Fat. Grams.	%	N. Grams.	%	Fat. Grams.	%
Health	3075	19·4	119·9	1·5	7·7	6·7	5·6	17·9	92·3	112·9	94·4
Pancreatic obstruction	3976	13·12	196·85	5·25	40·0	143·80	73·05	7·87	60·0	52·05	26·95

In Table 4 it is seen that in the healthy man the fæces contained 1·5 grams of nitrogen, *i. e.* 7·7 per cent. of the total nitrogen given, consequently 92·3 per cent. of the total nitrogen given had been absorbed. When we compare this with the unhealthy boy's case it is seen that in an average of two days, during which the patient was on nitrogen equilibrium, the fæces contained 5·25 grams of nitrogen, so that 40 per cent. of the total nitrogen given was eliminated in the fæces, and 60 per cent. only had been taken into the system to be made use of in metabolism.

As regards the fat, in Rübner's healthy man only 6·7 grams were excreted in the fæces, *i. e.* 5·6 per cent.; whereas in our boy's case (of probable obstruction to the pancreatic duct) the fæces contained 143·80 grams of fat, *i. e.* 73·05 per cent.,—so that only 26·95 per cent. of the fat given was absorbed from the intestines and rendered capable of being made use of in metabolism.

The two cases seem fair ones to compare, as the quantity of food given was about equal in both; the only difference being that while the boy received a larger quantity of fat in his diet, Rübner's received a larger quantity of nitrogenous food.

Turning now from what the results given in these tables show as regards absorption to the actual nourishment of our case, it may be as well to express it in the form of calories,—that is to say, the quantity of heat necessary to raise one kilogram 1° C.

[1] Rübner, 'Zeit. f. Biol.,' 1879, vol. xv, p. 115.

From Rübner's[1] calculations we obtain the following results:

1 gram proteid converted into urea, uric acid, ammonia, &c. . = 4·1 calories.
1 gram fat converted into carbonic acid and water . . = 9·3 „
1 gram carbohydrate converted into carbonic acid and water . = 4·1 „

In metabolism experiments it is customary to reckon that 100 grams of proteids contain on an average 16 per cent. of nitrogen, so that if we multiply the quantity of nitrogen by 6·25 we get the quantity of proteid it represents.

As in our boy's case we did not estimate the quantity of carbohydrates, an average of the other analyses has been taken.

If the quantity of food given to our patient be converted into calories we find—

	Grams.		
Proteid . .	82·51 × 4·1 =	338·25	calories.
Fat . .	195·85 × 9·3 =	1830·71	„
Carbohydrate .	198·75 × 4·1 =	814·87	„
		2983·83	„

Consequently the boy had received in his diet 2983·83 calories, and as he weighed 37·4 kilos. (78 lbs.) during the days of observation, he received 78·9 calories per kilo. in his food.

Numerous observers have found that a normal man on an average requires from 30 to 40 calories per kilo. to maintain his weight according to the muscular work he is doing, and that 32 calories per kilo. is sufficient for most people doing an ordinary amount of muscular exercise. So our boy received in his diet twice the quantity of nourishment necessary to maintain his bodily weight, and yet, notwithstanding this, he lost weight.

The loss of weight is partly explained by the greatly diminished absorption of food which we found by the analysis of the fæces to have occurred, from which is seen the importance of analysing both the urine and fæces before formulating a diagnosis in a case like his.

If from the quantity of food given we now subtract the quantity we found by analysis to have remained unabsorbed from the alimentary canal, we get the following results. From the carbohydrates having in our case not been calculated, I have taken as my standard the results found by Abelmann. He found in partial extirpation of the pancreas that only 71·78 p. c. of the carbohydrates given in the food were absorbed from the intestines.

[1] Rübner, 'Zeit. f. Biol.,' vols. xix—xxi, 1893–5.

Consequently in the case of the boy we find—

	Given.	Unabsorbed.				
Proteid .	82·5	− 32·75 =	49·72	× 4·71	= 203·85	calories.
Fat .	196·85	− 143·80 =	53·05	× 9·3	= 493·37	„
Carbohydrates	198·75	− 43·00 =	155·75	× 4·1	= 638·58	„
					1336·80	„

From these calculations it is seen that, instead of the boy absorbing into his system 2983·83 calories, he only absorbed 1336·80 calories; that is to say, only 36 calories per kilo.

On turning to Table 3 we see that he weighed 37·8 kilos. while on ordinary diet. On the first day of milk diet (Dec. 14th) his weight remained the same, while on the third day (Dec. 15th) it fell to 37·6 kilos., and on the fourth day (Dec. 16th) to 37·4 kilos., and remained so (on the 17th); whereas on resuming ordinary diet (on the 18th) it rose to 37·6 and (on the 19th) to 37·8 kilos.

The results of our analysis show that during the boy's milk diet, while taking a large quantity of food, he only absorbed a small part of it, but at the same time he absorbed as much as 36 calories per kilo., and in spite of this he lost weight; from which it appears, that although from 32 to 34 calories per kilo. per diem would have been ample for him to keep up his body weight if in health, it was insufficient under the abnormal circumstances under which he laboured.

We must, therefore, conclude that not only was there in his case a disordered absorption of food from the alimentary canal, but there was also a defective assimilation of what was absorbed.

The following table shows the changes the milk fat underwent during its passage through the alimentary canal in the case of the boy under observation.

TABLE 5.—*Showing the composition of the fat in the fæces of a boy suffering from probable obstruction of the pancreatic duct, and the composition of fat in the milk given.*

	Total fat.	Neutral fat.		Free fat acids.		Fat acids as soap.		Cholesterin.	
		Total.	p. c.	Total.	p. c.	Total.	p. c.	Total.	p. c.
Milk	196·85	191·000	97·02	5·690	2·89	0·121	0·06	0·160	0·08
Fæces :									
16th	149 72	59·051	39·44	54·348	36·30	26·270	17·55	10·051	6·71
17th	137·87	49·149	35·65	61·355	44·50	16·135	13·15	9·231	6·70

In Table 5 we find the quantity of neutral fat taken has diminished from 191 grams to 59·051 and 49·149 grams respectively, so that a large quantity of it has either been absorbed during its transit along the alimentary canal, or, in spite of the absence of the pancreatic secretion, it has been broken up into fat acids, &c.

In the milk given, although there were only 5·690 grams of free fat acids, yet 54·348 and 61·355 grams were found in the fæces. From this it is seen that we can at least account for the disappearance of part of the neutral fat from the alimentary canal by its having been split up into free fat acids in its passage along the intestines, seeing that they were increased tenfold.

As regards soaps, their quantity in the milk was only 0·121, while in the fæces it was no less than 26·270 and 18·135 grams.

Thus, in spite of the pancreatic secretion being absent, the neutral fats have not only been split up into free fatty acids and glycerine, but the fat acids have been able to find in the intestines an alkali wherewith to form soap.

The amount of cholesterin in the milk was only 0·16 grams, while the quantity found in the fæces was 10·051 and 9·231 grams respectively. This increase cannot be regarded as being due to a chemical change in the milk, but is in all probability due to a quantity of cholesterin being eliminated by the bile, or perhaps due to intestinal secretion.

That the above chemical changes should have taken place in the milk fats during their sojourn in the alimentary canal in the boy might argue against the idea of the absence of the pancreatic juice really occurring, had not other experiments shown that the same thing occurs in animals when we have undoubtedly not only hindered the flow of pancreatic juice into the intestines, but removed the entire gland.

I shall now give a table showing the results found in the case of the boy with supposed obstruction of the duct, and those I found in the fæces of dogs which had had their pancreas extirpated.

TABLE 6.—*Showing average composition of fat in the fæces of a normal dog on milk diet, compared with one from which the pancreas had been removed, placed side by side with the average result obtained in the two days' analysis in the case of the boy supposed to be suffering from obstruction of the pancreatic duct.*

	Total fat.	Neutral fat.	Free fat acids.	Soap as free fat acid.
	p. c.	p. c.	p. c.	p. c.
Normal dogs	100	34·17	58·65	7·19
Pancreas extirpated . . .	100	33·90	55·25	10·84
Boy with obstructed pancreatic duct	100	37·55	40·40	15·35

It is seen in Table 6 that, if we take the total ether extract of the fæces as representing 100, the quantity of neutral fat contained in it is in normal dogs 34·17; while in those from whom the pancreas was artificially removed, as well as in the boy, we get respectively 33·90 and 37·55 per cent.

In the normal dogs, while the free fat acids are 58·65 per cent., in dogs without the pancreas and in the boy they are respectively only 35·25 and 40·40 per cent. On the other hand, the soaps as represented as free fat acids are in normal dogs only 7·19 per cent., while after pancreatic extirpation they are increased to 10·84 per cent., and in the case of the boy they are 15·35 per cent. Consequently these cases very closely resemble each other in as far as neutral fat and fat acids are concerned. In fact, from merely the analysis of neutral fat and fat acids one would be unable to say whether the pancreatic juice was present or absent. In the case of the soaps we see that there is a slight tendency to excessive formation, or, I should rather say, an excessive excretion of soap in the stools when the pancreatic juice is hindered from reaching the intestines. This may be regarded as most remarkable, since when the pancreas is either entirely removed, or its secretion is merely prevented reaching the alimentary canal, there is either a non-absorption or a greatly diminished absorption of fat from the intestines.

According to former ideas, this non-absorption would have been attributed to the fat-splitting-up action of the pancreatic juice no

longer coming into play, and from the fats not being broken down, no emulsification taking place, and therefore no absorption.

In the case of the dogs, as well as the boy, it is seen from the above analysis that, in spite of the absence of the fat-splitting ferment of the pancreas, the fats during their passage through the alimentary canal are, by some means or another, broken up, and not only form free fat acids, but also soaps. Yet, in spite of this fact, they are for some reason or another not absorbed.

It may be as well to try and explain by the light yielded by the analyses what is the probable state of affairs in the case of the boy.

The results of the analyses show us that large quantities of fat appeared in the stools, no less than 73·05 per cent. of the total quantity given. And, still further, that the proteids excreted in the fæces are far above the amounts normally found, so that 40 per cent. of the nitrogen given has been excreted in the stools.

The foul odour of the stools which was a constant feature in the case of my dogs, was at the same time specially marked in the case of this boy, so that it is worthy of note. For this fact led me to believe that for some reason or other the pancreatic secretion was not reaching the alimentary canal. Yet that this is not due to an absence of the pancreas, or its destruction by disease, is shown by the fact that at no time was sugar present in the urine, and therefore the evidence is only in favour of an occlusion of the pancreatic duct.

Moreover, the morbid anatomical condition which has led to this obstruction appears to be some chronic inflammatory stricture of the duct. For as the analyses have shown us that bile reached the intestine, the common bile-duct must have remained free. We cannot therefore suppose that the common orifice of the bile and pancreatic ducts can even be partially obstructed. For seeing that bile and pancreatic juice are secreted at the same pressure, namely, 260 mm. of water, it is hardly possible that one only should be hindered reaching the intestines if both were implicated. As the pancreas is, however, known to have very frequently accessory ducts, and in some rare cases the ducts enter the duodenum separately from the common bile-duct, the accompanying diagram will, I think, assist in explaining what seems to have occurred.

As the commonest form of accessory duct is one entering the duodenum nearer the stomach (*d*), and we know from the history of the case that the boy suffered from gastritis previous to the appearance of the foul-smelling motions; it is conceivable that

either the main duct of the pancreas (*a*) may be absent, and only the accessory duct present, and if so that an inflammation spreading from the stomach down the duodenum may have involved it, without having extended far enough to have likewise involved the orifice of the common bile-duct (*c*). In this way there might be complete obstruction of the pancreatic and not of the bile duct. Or

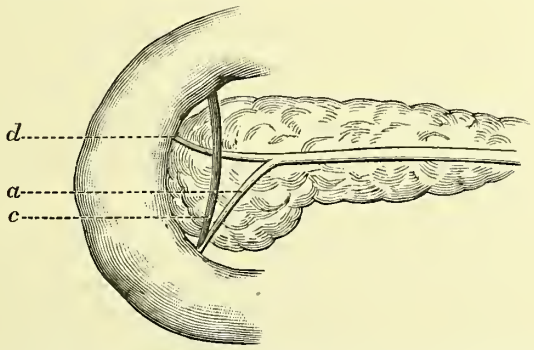

Diagram to show how an accessory pancreatic duct may open away from the main duct, the latter opening as usual into the duodenum with the common bile-duct.

we may even imagine that both the main (*a*) and the accessory pancreatic duct (*d*) are present, and that the inflammation has extended up the accessory duct so far as to involve the main duct also. The diagnosis being obstruction of the pancreatic duct, and it being impossible to give any drug which could with any probability cure such morbid condition, it became necessary to consider what could best be done in the case, and the following was arrived at.

Abelmann having found that feeding dogs after removal of the pancreas with raw pancreas caused an increased absorption of fat, I recommended Dr. Auld to give the boy raw pancreas. From February 28th until March 10th, 1895, this was done, and during this time the quantity of oil passed with the stools was very markedly decreased, although it did not entirely disappear. The foul smell was also absent, but as the boy was taking at the same period calomel and potassium benzoate, both powerful intestinal antiseptics, we can hardly put this last fact down to the effect of the raw pancreas. The parents then refused to continue the pancreas treatment, in consequence of the boy's having been ill after eating

a supposed bad pancreas. And since then oil has again been present off and on in the stools, and Dr. Auld has unsuccessfully endeavoured to get the parents to allow the boy to resume taking the pancreas.

During the last four months, what with careful dieting and treatment, the patient has increased 2 lbs. in weight.

In conclusion it may be said, from the results of the analyses in this boy's case, and of the dog's from which the pancreas was either partially or completely removed, that the pathology of the absence of pancreatic juice from the intestines is much more complicated than what was formerly supposed. Seeing that not alone was there diminished absorption of fat, so that only 26·95 p. c. of the total given was absorbed in the case of the boy, and from 4 to 37 p. c. in the case of the dogs I experimented on, but at the same time the proteid absorption was greatly diminished, so that in dogs only 18 p. c. and in the boy 60 p. c. was absorbed.

The results of the analyses of the fæces in the boy show that the non-absorption of fat in pancreatic duct obstruction is not due, as is generally supposed, to any want of the splitting up of the neutral fat into fat acids, glycerine, and the formation of soaps; but, on the contrary, is dependent on some as yet unexplainable cause.

When the quantity of food given is increased to above the quantity necessary for a healthy individual, so that the quantity absorbed may be equal to the number of calories necessary to maintain the body weight in health, it is nevertheless owing to improper metabolism insufficient to keep the body weight up to the normal standard when the pancreatic duct is obstructed. By still further increasing the quantity of food, however, the body weight can be maintained, and not only so but we see that, in the case of this boy, careful dieting, together with treatment, not only kept up his body weight, but even sufficed to cause a gain of 2 lbs. in the space of four months.

Appendix.

Methods employed in this investigation.—With the first meal a quantity of charcoal was given, so that the fæces of that meal might, by their dark colour, be distinguished from those belonging to the previous one. With the last meal charcoal was also given for a similar purpose.

In the case of the dogs, they were given charcoal but otherwise kept fasting before commencing the dieting.

The quantity of nitrogen was always estimated by the method of

Kjeldahl. And in the case of the food and fæces at least four samples were analysed, and the quantity of nitrogen calculated from the average. In the case of the urine, on the other hand, two analyses were found sufficient.

In analysing the fats some of the fæces were first extracted with alcohol and then with ether in a Soxhlet's extractor, and the two extracts, after being dried, were again treated with absolute ether, and the extract then weighed. The residue, after complete extraction with ether, was heated with dilute hydrochloric acid, dried, and again extracted with ether, so as to obtain the fat acids liberated from the soaps. The quantity found in the first ether extract, together with the soap, is in the above tables termed total fat.

In order to separate the neutral fat, fat acids, and cholesterin, the first ether extract was warmed with a solution of sodium carbonate, to saponify the free fat acids, and, after drying, the neutral fat and cholesterin were extracted with absolute ether. The free fat acids were calculated by the loss of weight.

The new ether extract was then treated with a freshly prepared alcoholic solution of metallic sodium (NaOH), and, after drying, extracted with ether to separate the cholesterin. It was often found in practice necessary to repeat the process several times before pure cholesterin could be obtained, and in all cases it was repeated until there was no longer any loss of weight. By subtracting the quantity of cholesterin from the neutral fat and cholesterin the quantity of neutral fat was obtained.

In order to study the absorption of milk fat and proteids in the case of the boy a quantity of milk was sterilised, and a litre of it analysed to form a standard of comparison. The method of analysis was exactly similar to that employed in the case of the dogs.

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